

REGIONAL INNOVATION SYSTEM (RIS): CONSTRUCTION MODEL, INNOVATION BARRIERS AND PERFORMANCE EVALUATION

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ABSTRACT

How to establish and improve regional innovation systems (RISs) is a significant theoretical and practical issue facing Chinese academia and all levels of government. This paper attempts to make an in-depth study of China's RIS construction, the innovation barriers, and innovation performance evaluation. The idea of an RIS construction and, development model as well as policy arrangements are in line with the characteristics and requirements of China's regional economic and social development. The innovation performance evaluation method is of the interest due to the inherent requirements of the RIS. This paper seeks to provide guidance and reference in order to improve the construction of China's RISs.

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INTRODUCTION

The concept of a regional innovation system (RIS) was first proposed by Cooke (1992). He defined the RIS as a system to engage in interactive learning for enterprises and other institutions

via the institutional environment characterized as “embeddedness.” This definition can be further explained by analyzing three aspects: Firstly, "interactive learning" is the equivalent of a collective asset owned by different types of actors in a production system through the interaction and combination of knowledge. Secondly, the term "environment" refers to an open, complex geography, including rules, standards, values, human, and material resources. Thirdly, "embeddedness" includes the processes of creating and reproducing all economics and knowledge inside and outside an enterprise. These processes are generally created and reproduced by a particular form of social interaction. In addition, many domestic and foreign scholars have different definitions for an RIS. Although there are some differences, the basic connotation is uniform, namely: (1) The RIS is a social system, and innovation is the result of social interaction between economic actors; (2) It not only emphasizes the innovation performance of the actors, but it also pays more attention to the interaction between the different actors; (3) Institutional factors are placed in a prominent position and taken into account; and (4) It is for the purpose of promoting regional innovation activities. The RIS concept provides a useful framework for us to further understand the process of innovation in regional economics. Building an RIS is the fundamental guarantee of improving a regional innovation capacity. A perfect and vibrant innovation system can maximize innovation efficiency, reduce the cost of innovation, stimulate effective integration and utilization of resources needed by innovation, and make a variety of services more comprehensive and supplied in a more timely fashion. Therefore, the study of RISs undoubtedly has great theoretical and practical significance.

In recent years, the construction of China's RIS has been continuously developing. In the central regions of China, innovative awareness is enhanced, and innovation input has increased. The area's lower export-oriented economy was less affected by the financial crisis. Industries in the eastern region transfer innovation to industries of the central region depending on the level of innovation development of each industry. Overall though, the eastern regions still have a strong regional innovation capability. The western regions present no overall similar characteristics in innovation capacity. Some areas rise faster, and some decrease rapidly. The strength and efficiency of different regional innovations are quite different. For example, Guangdong and Jiangsu's innovative strength is far ahead of other regions; the innovation efficiencies of Beijing, Shanghai, and Tianjin are far ahead of other regions; the innovation potentials of Chongqing, Inner Mongolia, and Anhui are the greatest. Overall, the current regional innovation capability of China has formed a stable pattern. The eastern regions are the backbone of innovation. Areas with strong innovative ability, such as Tianjin, Jiangsu, Shandong, Guangdong, have a large room for improvement in innovation. At the same time, there has evolved a balanced development of the three larger regions of eastern, central, and western China. However, there is still a long way to go for fully balanced development. The enhancement of innovative ability in the northeast, the old industrial base has a long way to go. The western regions have geopolitical differences and their innovative capabilities also face many difficulties.

BASIC MODEL OF RIS CONSTRUCTION

Based on previous research on RISs and RISs construction practice, a successful construction model of RIS in China can be divided into three main types: Innovation system modes based on industrial clusters, innovation system mode based on active learning, and innovation system mode across various administrative regions.

Innovation System Modes Based on Industrial Clusters

Based on modern regional economic development theory, industrial clusters not only reduce transaction costs and improve efficiency, but also improve incentives to create information and specialized systems. More importantly, the industry cluster can improve the conditions for innovation, and is conducive to the formation of new enterprises. Therefore, the study of the innovation system has been closely linked to the research of industrial clusters. Asheim and Isaksen (2001) thought the RISs were regional clusters surrounded by supporting mechanisms. According to their view, an RIS mainly consists of two types of bodies and the interaction between them: The first is enterprises in the regional leading industry clusters; the other is the basic infrastructure, such as research and higher education institutions, technology diffusion agencies, vocational training institutions, industry associations, and financial institutions. These institutions play an important role in supporting regional innovation. Based on the above definition, Andersson and Karlsson (2002) proposed a cluster-centric RIS structure. For now, the industry cluster-based innovation system is a more advanced model. Some economically developed regions in China, such as Zhejiang and Guangdong, are forming, or have formed such an RIS mode. Qiyang Liu (2003) think that the targets of industrial clusters-based RIS construction must highlight the following aspects: Provide the original innovation supply in specific areas, maintain and enhance the competitiveness of the specific industries and regions, and support their social needs. The RIS construction model based on industry clusters must follow these general principles: maximizing competitiveness, phasing in cluster development, orienting industry and market, having a low-threshold for ease of implementation, maximum sharing of public resources, and positioning interaction between businesses with government. The content structure of the RIS should include the following: strategic positioning of industry guidance and innovative measures; common technology platform-building measures; technology, information and management services support system aiming at SMEs; targeted industrial policies regions can provide; positive incentive investment and innovation; international expansion measures; human capital development system; an atmosphere of encouraging informal exchanges and leading non-governmental organizations (NGOs) into industrial development; and an industry cluster monitoring system. The policies based on industrial clusters promoting the RIS to develop in depth include: closely integrating industrial clusters and RIS construction;

having industrial policies in the region change to industrial clusters and regional innovation policies; establishing the science and technology innovation platform based on industry clusters and form the innovation network with strong innovation abilities; eliminating system barriers of regional industry clusters and integrate regional economic resources; and fostering social and cultural environments to promote industrial agglomeration and regional industrial cluster merging into the global industrial value chain system.

Innovation System Mode Based on Active Learning

Chinese scholars Zhang Yu and Xie Fu Ji (2005) first proposed the theoretical framework of an innovation system based on active learning. Comparing with Freedman & Nelson's innovation system model and Porter's diamond model, an innovation system based on active learning not only emphasizes the links and interactions between innovative actors within the innovation system, but it also emphasizes the interaction between all of the elements of the innovation system. It also stressed that a region's innovation performance depends not only on the internal efficiency of the innovation system, but also on the external efficiency links of the innovation system. Therefore, the analysis framework of the innovation system based on active learning is more suitable for the developing economies, including developing countries and regions, and as well as industrialized countries lagging behind in areas of technology. The main measures of constructing the innovation system based on active learning are as follows: strengthen contact with external knowledge and promote the acquisition of new technology; build a technology proliferation network making the technology transfer centers of universities and research institutions the node, enhancing the role of the institutions in support of technology transfer and diffusion; strengthen the links between local enterprises and companies; and integrate into the global production system access to new technologies.

Innovation System Models Across Various Administrative Regions

The innovation system mode across various administrative regions refers to a system that consists of enterprises, scientific research institutes, universities, and government, all of which are closely linked to various administrative regions and interacts in a unified environment for innovation. China's RIS is based mainly on administrative regions. Under the current administrative system, the kind of innovation system tends to strengthen the awareness of administrative regions, artificially cut off innovation contact, and even to some extent limit innovation and the flow of the main elements, especially in the case of conflict between regional interests and business interests, which reduce the efficiency and capabilities of the RIS, and even the national innovation system. With the intensification of production globalization and

regionalization, the refinement of division of labor, and the extension of the industry value chain, there is an increasingly close cooperation between the regions. Various administrative cooperation and integration processes become the main trend of regionalization development. With the strengthening of ties and cooperation between the main innovations in the neighborhood, some innovation systems across administrative regions are taking shape. Chinese scholar Kaiyuan Long (2004) put forth the theory of an innovation system based on various administrative regions. The key points are: (1) the various administrative innovation systems are characterized by innovation diversification, intensive linkages across regions, as well as a clear division of labor of innovation activities in multi-administrative regions; (2) the basic construction framework of the innovation system across regions mainly include the overall coordination mechanism and system, the common market and the environment, geographical division of labor and collaboration mechanisms, and their networks; (3) the formation and evolution of the innovation system across administrative regions is divided into a nascent stage, the webs stage, and systematic stage; (4) the construction barriers and problems of the innovation system across administrative regions are prominent administrative barriers, different innovation environment, as well as the weakness of common environmental construction; and (5) the main measures of constructing an innovation system across administrative regions include jointly carrying out strategic research and planning on innovation and development, establishing coordinating institutions of the innovation system across administrative regions, accelerating the construction of interconnection and infrastructure, opening up and sharing scientific and technological resources, jointly building innovative carrier and technology trade markets, and carrying out joint research on major science and technology projects.

Comparison of Three RIS Construction Models

China's three successful RIS construction modes can be compared based on the three aspects of the mode characteristics, policy recommendations, and typical regions (Table 1). These modes are similar when emphasizing knowledge links between the main innovations, but these links create a difference within and outside the region, which is an essential characteristic.

If there is a lack of local main innovation in some regions, it is appropriate to build an innovation system based on active learning. If industrial clusters develop, it is better to build the innovation system based on industrial clusters. If there are close links among regions, construction across districts should be closely inter-regional, and the innovation system across administrative regions should be built. Previous studies have demonstrated that the construction of RISs doesn't have an optimal mode. Only by recognizing the local realities can the optimal mode be chosen. China has major differences in its regions, and its innovation resources and the environment vastly differs in these regions. The regional stages in innovation system construction are also different. We

can't simply copy the experience of a developed RIS in other regions. We should consider the characteristics and advantages for different economic and technological development of different regions to highlight regional characteristics and advantages while cultivating and developing local industrial clusters.

TABLE 1. COMPARISON OF THREE MODELS

Mode	Characteristics	Policy Recommendations
Innovation system mode based on industrial clusters (Used in developed region)	<ul style="list-style-type: none"> ● Developed industrial clusters ● Frequent communication in a region 	<ul style="list-style-type: none"> ● Closely combine industrial clusters and the construction of innovation systems ● Transform industrial policy to promote industrial clusters and regional innovations ● Establish a scientific and technological innovation platform and form a network of scientific and technological innovation exchange ● Eliminate institutional barriers for regional industrial clusters, integrate regional economic resources, and foster a regional socio-cultural environment ● Bring regional industrial clusters into the global industry value chain system
Innovation system mode based on active learning (Used in developing region)	<ul style="list-style-type: none"> ● Lack of relevant local entities ● Knowledge is closely linked inside and outside a region 	<ul style="list-style-type: none"> ● Obtain new technologies by strengthening contacts with external knowledge sources ● Build a technology diffusion network by creating technology transfer centers at universities and research institutions ● Strengthen the link between local enterprises and multinational companies, and integrate them into the global production system
Innovation system mode across various administrative regions (Used in urban agglomerations)	<ul style="list-style-type: none"> ● Diversified innovation entities ● Intensive contact across various regions ● Clear division of labor in innovation activities across various regions 	<ul style="list-style-type: none"> ● Jointly carry out strategic research and planning on innovation and development ● Establish a coordinating body for the innovation system ● Accelerate the construction of interconnections and infrastructure ● Implement scientific and technological resources open and shared with all entities ● Build a joint innovation support program ● Build a joint technical trade market ● Carry out joint research on major scientific and technological projects

In order to promote the construction of an RIS, inter-regional links and interactions must be emphasized. An important feature of the innovation system is the closed and complex network relationships between subjects in the system. With a higher degree of networking, the ability to innovate is stronger. Therefore, the construction of RISs must avoid duplication, being closed and restrictive in some areas. We should respect regional economic development, pay more attention to economic regions with strong internal economic ties, and cultivate collaborative networking of regional innovation across provinces and cities to realize a grander scale of coalition and cooperation.

The three RIS construction modes are not mutually exclusive, but rather complement each other. For example, Shenzhen, not only emphasizes the development of competitive industry clusters, such as high-tech, modern logistics, financial services and cultural industries, but also actively integrates into the Pearl River Delta, and has close links with domestic and overseas scientific research institutes and institutions of higher learning.

Therefore, the construction of China's RISs is a long and complex process, which must rely on the long-term unremitting efforts of local governments and enterprises. With the continual push forward of the construction of RISs, the construction mode should be dynamic rather than the static.

CHINA'S REGIONAL INNOVATION BARRIERS, THEIR MEASUREMENT, AND POLICY RESPONSES

The innovation barrier refers to factors hindering innovation activities in the RIS. The research on regional innovation barriers stems from Isaksen's (2001) pioneering work. He identified three types of barriers that impede innovation activities in the RIS: organizational thinness, fragmentation, and lock-in. Although the RIS exists, a closed and rigid network of the system will result in a "locked" state. Most of the subsequent policy research on RISs is based on the study mentioned above. The discussions of the regional innovation barriers, measurements and the policy responses, such as Tidting and Trippel's research (2004), help further expand policy research on RISs.

Classification of Innovation Barriers

The report of "China's regional innovation capacity", researched, edited, and published by the

China Science and Technology Development Strategy Research Group, is one of China's most influential writings about regional innovation capability evaluation. The report concluded that regional innovation capability is reflected in transforming knowledge into new products, new processes, and new services. This capability is made up of five elements, and we classify the regional innovation barriers in accordance with them:

(1) Knowledge creation barriers

Knowledge creation capability is the basis of a technological innovation in a region. Innovation is the process of transforming knowledge into new products, new processes, and new services; so, no knowledge, no innovation. "Knowledge" refers to scientific and technological knowledge directly serving in innovation. Knowledge creation barriers mainly refer to the lack of government investment in science and technology. This results in the main bodies of knowledge creation, such as universities and research institutions, providing low-levels of knowledge creation. Scientific and technological personnel are often lacking and the efficiency of knowledge creation is still relatively low.

(2) Knowledge acquisition (or knowledge flows) barriers

The innovation in a region is isolated and closed without knowledge flow, so innovation is not systemic. Many studies have shown that the aim in establishing innovation systems is to promote the flow of knowledge of a country or a region; in particular, to promote the effective flow of knowledge between research and development institutions, enterprises, and intermediary organizations. Knowledge acquisition barriers are mainly reflected in linkages which are not close enough between enterprises and research institutes, as well as colleges and universities. At the same time, there is a larger gap in scientific and technological cooperation, technology transfer, and attracting foreign investment. In addition, deficient aspects of the environment for innovation, such as infrastructure and, the financial environment for enterprise technology development may also affect the capabilities of knowledge acquisition.

(3) Enterprise innovation barriers

Higher education institutions as well as, research and development institutions are an important source of knowledge creation, but in the RIS, the enterprise is the main actor. Enterprises directly transform new technologies into commodities and interface with the market. At the same time, the market effectively leads the direction of science and technology research through enterprises. The weakness of innovation capabilities of enterprises seriously restricts the development of the RIS.

(4) Innovation environment barriers

Innovation environment refers to the environment for the generation, flow, and application of knowledge. Environmental factors that affect the RIS include the innovative service level, the developing level of the innovation infrastructure, the level of regional market demand, the quality of workers, the innovation fund, the financial environment, and levels of entrepreneurship. The biggest advantage of the innovation barriers classification is that it is easy to quantitatively measure and can provide more targeted policy recommendations for the construction of China's RISs.

Measurement of Innovation Barriers

As mentioned above, the biggest advantage of the classification of the innovation barriers is that it is easy to make the quantitative measurement. Therefore, the "absolute innovation barriers" and "relative innovation barriers" characterizing the size of the innovation barriers are proposed.

(1) Absolute innovation barriers

Absolute innovation barriers are mainly used to characterize the level of development of regional innovation barriers noting that the greater the values, the greater the innovation barriers. The formula is as follows:

$$B_a = \frac{1}{E} \times 100 \quad (1)$$

B_a: absolute innovation barriers E: utility value of the index of regional innovation ability

(2) Relative innovation barriers

Relative innovation barriers are mainly used to characterize the imbalance of regional innovation barriers noting that the larger the values, the greater the differences of the levels among the various innovation barriers in a region. The formula is as follows:

$$B_r = \sum_{i=1}^{n-1} \sum_{j=i+1}^n |R_i - R_j| \quad (2)$$

B_r: relative innovation barriers R_i, R_j: national rankings of innovation capacity of the regional utility values n: numbers of indicators of innovation barriers

By using formula (2), people can understand that relative innovation barriers are calculated by the national rankings data of the utility value of the index of innovation ability rather than the utility value of the data. The utility values of the index of innovation capability are not directly comparable.

Innovation Barriers and Policy Responses

(1) Policy responses to knowledge creation barriers

Increasing investment in science and technology is an important way to generate new knowledge. Government should establish a stable increasing mechanism of fiscal investment in science and technology to ensure that the growth rate of science and technology funds is significantly higher than that of the fiscal regular revenue growth, and to gradually increase the proportion of fiscal investment in science and technology in GDP. Government should adjust and optimize the investment structure, and strengthen support for basic research, cutting-edge technology, social studies, science and technology basic conditions and popularization. Government should enhance its ability to mobilize the whole society to allocate resources, and to form a diversified, multi-channel, high-efficiency investment system in science and technology.

The lack of scientific and technological personnel is the major reason for generating knowledge creation barriers. Having all kinds of expertise, especially high-quality and high-level innovative talents, is the basis of building an RIS. There should be increased efforts to train personnel. Relying on a major talent training plan, and scientific and technological projects, can develop a number of technological leaders and synergize talents, such as between strategic scientists, academic leaders of advantageous disciplines, and scientific and technological entrepreneurs. Second, there should be efforts to attract talent. Finally, there should be the establishment and improvement of the talent evaluation and incentive mechanism, including establishing an evaluation index system of creative talents focused on performance and ability, actively exploring the technical elements of capitalization, encouraging technology, management, and other factors in distribution, and improving the income distribution system and the talent incentive mechanism.

The construction of a public technology platform can greatly improve utility of and conserve social resources. The platform is also commonly used in the practices of developed countries to improve the level of corporate research and competitive strength, and to develop and construct the public technical service platform for the majority of small and medium-sized enterprises. At some point, there should be a speeding up of the construction of the public technology platform composed of multiple entities, such as government, enterprises, universities, and industry organizations, operated by market mechanisms, opened for society, and providing services for SMEs.

(2) Policy responses to knowledge acquisition (or knowledge flows) barriers

Cooperative innovation can combine the advantages of enterprises, universities, and research

institutions, which is an effective way to promote regional innovation activities. For their own needs and conditions, enterprises should make full use of external technical superiority to make up for their lack of innovation and reduce the risk of lost innovation. Research institutions should be consciously market-oriented, strengthening cooperation with enterprises and promoting the rapid transformation of scientific and technological achievements. At the same time, there should be a strengthening of the construction of science and technology parks at universities and improving the output and conversion rates of scientific and technological achievements.

Foreign direct investment brings capital and equipment. At the same time, it also brings production technology, management techniques, and a large number of technical tactics, which significantly improve the region's level of industrial technology and optimizes the industrial structure. Although China has become the best at attracting foreign investment in the world, the problem is that the quality is not high and the geographical distribution is distinctly un-balanced. In order to attract foreign investment actively, effectively and safely, Jingyan Hu, Secretary of Trade in Services, Chinese Ministry of Commerce, raised nine considerations: (1) Provide classification guidance on foreign investment, and further develop the role of foreign investment in promoting regional economic developments; (2) Strengthen the guidance to optimize the industrial structure of foreign investment and encourage multi-national corporations to set up more R&D centers in China; (3) Encourage domestic research institutions and enterprises to cooperate with multinational corporations and maximize the technology spillover effects of foreign investment; (4) Vigorously develop a service outsourcing and actively undertake the multi-national outsourcing business to promote the development of a modern service industry; (5) Encourage foreign investment in the form of mergers and acquisitions; (6) Improve the evaluation index system of foreign capital quality and improve the level of foreign investment management; (7) Strengthen the supervision of foreign-invested enterprises and place emphasis on corporate social responsibility; (8) Further accelerate the development of the National Economic and Technological Development Zone to serve as a leading model; and (9) Further improve the environment for foreign investment, especially the soft investment environment.

Science and technology intermediary institutions mainly refer to institutions providing social and professional services for scientific and technological innovation bodies to support and promote innovation activities. These institutions include productivity promotion centers, technology business incubators, technology consulting and evaluation agencies, technical trading institutions, and venture capital investment service agencies. These institutions promote the integration of government, business, industry, science, and research, and jointly promote the regional innovation system's development. Additional measures to promote the development of China's science and technology intermediaries are as follows: strengthen the government's policy guidance on science and technology intermediaries, vigorously supporting the development of various scientific and technological intermediaries; strengthening the cultivation of employees of

scientific and technological intermediaries, promoting the construction of a network platform of science and technology intermediaries. The credit environment of the region is very important to the flow of knowledge within the RIS. A good regional credit environment helps reduce transaction costs of various actors in the RIS and helps enhance the flow of knowledge within the system. The flow of knowledge requires a social environment of good credit and compliance within the rules of the game. Therefore, in the process of building an RIS, there needs to be a social credit environment from moral, legal and intermediaries' points of view, and a favorable social environment for enterprise technology innovation.

(3) Policy responses to the innovation barriers

Years of experience tells us that there is a simple technology-oriented tendency of research and development activities in scientific research institutions, which focuses on the advance of technical parameters and indicators, but lacks significance when it comes to the laws of market demand and is often behind in terms of marketing timing. This is the root cause of the low technological achievements conversion rates in many years. Under the conditions of a market economy, enterprises are the main economic entity. Technological innovation activity is essentially an economic process. It is the enterprise that adheres to the marketplace and reflects market demand. In order to promote the enterprise to become the main entity of technological innovation, it is important to create a favorable policy environment. It is important to support an enterprise through the project, but even more important this support should be characterized by long-term policy. Only policy can truly mobilize hundreds of thousands of businesses to invest in technological innovation. Second, there should be vigorous support for the innovation activities of SMEs. Third, there should be support for enterprises to establish research institutions and engineering technology development and research centers, encourage universities and research institutes to enter into the enterprises' technological innovation institutions, encourage qualified enterprises to technically cooperate with foreign companies and large corporations, and establish a number of technology research and development centers, which are open and integrated at the foreign advanced level.

Industrial clusters keep enterprises and their trading partners, customers, suppliers, as well as education and R&D institutions in close contact. Industrial clusters enable an enterprise to better understand the market, provide differentiated products and new products to meet market demand in a timely manner, which can help the enterprise's product innovation and market innovation, improve its own research and development capabilities, strengthen the technical contact between enterprises within the group and technology diffusion, and promote the technological advances of the whole industry cluster. Through industrial clusters, many enterprises can integrate on the basis of specialization and cooperation and the organizational structure can constantly adjust, which accelerates the enterprise's organizational and institutional innovation. Asheim and Isaksen (2002) think an RIS is the regional cluster that is surrounded by supporting and

supported mechanisms. Liuqin Chen (2005) researched policies based on industry clusters for promoting an RIS to develop in depth: Closely combining industrial clusters and RIS construction, transforming from industrial policy into industrial clusters and regional innovation policies within a region, establishing a scientific and technological innovation platform based on industrial clusters and forming a network of scientific and technological innovation with strong creative ability, making efforts to eliminate the institutional barriers of regional industrial clusters, and integrating regional economic resources, fostering the social and cultural environment to promote industrial agglomeration areas, and promoting regional industrial clusters to integrate into the global industry value chain system.

Government procurement has the force of policy and has huge purchasing power. The procurement of how much, to whom, and how to procure it, will have a direct impact on corporate behavior. Government procurement in favor of independent innovation products and services will greatly stimulate the supply-side independent innovation enthusiasm. In developed countries, it is a common practice to implement government procurement policy supporting independent innovation, and promote technological innovation, product innovation, and upgrading of industrial structure by using government procurement leverage. Government procurement focusing on independent innovation is not automatic but rather is determined on the basis of bidding for innovation that has the most utility.

In relation to higher levels of technology products and services, government can set the factor minimum value of independent innovation, and independent intellectual property rights, and score them. When government procurement occurs, the products and services of independent innovation may be appropriate to be given price concessions.

(4) Policy response to innovation environment barriers

Innovation infrastructure refers to the utilities to provide services to the local innovation systems, which is an important condition for the construction of an RIS. Innovation infrastructure includes public libraries, public laboratories, public meeting rooms, public information service agencies and other physical facilities (also a public space for the exchange of ideas), and universal coverage of basic education, technical training of labor, entrepreneurship training, and other intangible services. Jici Wang (2001) thought that modern innovation infrastructure should emphasize the interaction between the main innovators, and create conditions for the exchanges and cooperation among them.

There should be a gradual establishment and improvement in diversified technology investment and financing systems based on government funds for guidance, enterprise investment as a

mainstay, financial institutions for the assistance, social capital and venture capital providing direction, and the guiding role of government investment. We should also enhance the ability of government investment to mobilize all of the society resource allocation through financial direct investment, tax incentives, and other financial investment, actively cultivate multi-form and multi-level risk investment entities, broaden the sources of funds, optimize the supply of venture capital, improve the venture capital exit channels, improve the credit rating standards and restraint systems of venture capital intermediaries, and establish and improve risk investment laws and regulations, and form sound development on a risk investment mechanism.

In order to speed up the pace of scientific and technological development and relevant legislation, the technology regulatory system and the protection of intellectual property rights should be a major focus. There should be research on and the formulation of the legal system around the key tasks of scientific and technological work, such as technology conditions platforms, science and technology intermediary institution-building; fully implementing "Scientific and Technological Progress Law," "Patent Law," "Promotion Law on the Transformation of Scientific and Technological Achievements," and other scientific and technological regulations and laws; making great efforts to strengthen legal advocacy of intellectual property rights and talents training; and establishing and improving the intellectual property management system of enterprises and research institutions.

AN EMPIRICAL STUDY ON PERFORMANCE EVALUATION

Innovation performance refers to the allocation efficiency of innovation resources. It is an important indicator of how to examine the operational state of an RIS. Previous studies have demonstrated that the data envelopment analysis (DEA) method can be used to analyze and compare the innovation performance of an RIS. Shunzhong Liu and Jiancheng Guan (2002, 2003) used the DEA method to analyze the characteristics of China's RIS and to evaluate the performance of each innovation system. According to the characteristics of the innovation system and innovation performance, they classified the various regions of China's RISs into different categories, and put forth recommendations about how to make regional innovation policy for each type of innovation system. Nasierowski and Arcelus (2003) also used the DEA method to investigate the efficiency evaluation of OECD national innovation system.

On the basis of previous studies, the intension is to carry out more in-depth discussion from the following aspects: (1) Use of a variety of DEA Models; (2) Expand one year of data to four years of data to increase the amount of information; (3) Re-examine the choice of input and output indicators; and (4) Consider some premises to use the DEA method, such as an isotonic

assumption (that is, the increase in the quantity of inputs and the number of outputs will not lessen). Ignoring these problems may lead to an error in the selection of indicators.

DEA's Basic Principle

DEA is the method used to evaluate the relative effectiveness of the same type of sectors (or units). The basic principle of measuring the efficiency is based on Pareto optimization. In the following ways, the decision-making unit is efficient: (1) Unless you add one or more inputs or reduce some of the other outputs, until output can no longer be increased; and (2) Unless there is a reduction of outputs or an addition of other inputs, until inputs can no longer be reduced. DEA's development began in Farrell's conception (1957) of default function type "non-parametric frontier analysis." After that, the CCR models developed by Charnes, Cooper & Rhode (1978) extended the Farrell's "single-input & single-output efficiency measurement model" to a "multi-input & multi-output model," and named the efficiency measurement method the "data envelopment analysis," that is "DEA." Later, the BCC model of Banker, Charnes & Cooper (1984) further broadened the CCR model's assumption of constant scale returns and considered the case of non-fixed production scale. This production function based on linear programming techniques to achieve the relative efficiency has the biggest advantage because it does not need to preset a function form when analyzing, to avoid the problem of predetermining the model. At the same time, DEA can handle the efficiency evaluation questions of "multiple outputs & multi-inputs." The model can self-assess weight and avoid the problem of determining the weight subjectively.

The basic idea of the DEA method for evaluation of an RIS regards provinces, municipalities, and autonomous regions of the innovation performance assessment as a decision-making unit (DMU). Suppose there are n DMU, each DMU_j ($j=1\dots n$) uses m innovation input x_{ij} ($i=1\dots m$), and produces s kinds of innovation output y_{kj} ($k=1\dots s$). Charnes, Cooper & Rhode (1978) blended the situation of "multi-input, & multi-output" into a situation of "single input & a single output" using weight coefficient v_i, u_k , and made the "virtual" output-input ratio as the efficiency measurement of the DMU. Therefore, if you want to evaluate a decision-making unit j_0 , we can construct the following CCR model:

$$\begin{aligned}
 & \max \frac{\sum_{k=1}^s u_k y_{kj_0}}{\sum_{i=1}^m v_i x_{ij_0}} = V_{\bar{P}} \\
 (\bar{P}) \left\{ \begin{aligned}
 & \text{s.t. } \frac{\sum_{k=1}^s u_k y_{kj}}{\sum_{i=1}^m v_i x_{ij}} \leq 1, \quad j = 1, \dots, n \\
 & u_k \geq 0 \quad k = 1, \dots, s \\
 & v_i \geq 0 \quad i = 1, \dots, m
 \end{aligned} \right.
 \end{aligned} \tag{3}$$

Wherein x_{ij} is the j^{th} decision-making unit, the i^{th} inputs; y_{kj} is the j^{th} decision-making unit, the k^{th} inputs; v_i is the weight of the i^{th} inputs; and u_k is the weight of the k^{th} inputs. This is a fractional programming problem.

Using the Charnes-Cooper transformation, we can translate it into linear programming problems of being equivalent and easier to handle.

$$(P) \left\{ \begin{aligned}
 & \max \mu^T y_0 = V_p \\
 & \text{s.t. } \omega^T x_j - \mu^T y_j \geq 0, \quad j = 1, \dots, n \\
 & \omega^T x_0 = 1 \\
 & \omega \geq 0 \quad \mu \geq 0
 \end{aligned} \right. \tag{4}$$

Wherein, $\omega = tv$, $\mu = tu$, $t = \frac{1}{v^T x_0}$

Linear programming (P)'s dual programming is:

$$(D) \left\{ \begin{array}{l} \min \theta = V_D \\ s.t. \sum_{j=1}^n x_j \lambda_j + s^- = \theta x_0 \\ \sum_{j=1}^n y_j \lambda_j - s^+ = y_0 \\ \lambda_j \geq 0, \quad j = 1, \dots, n \\ s^+ \geq 0, \quad s^- \geq 0 \end{array} \right. \quad (5)$$

In the above dual problem, a limit on the sum of the λ_j constitutes the following different envelope surface of the DEA models:

$$\sum_{j=1}^n \lambda_j = 1, \text{ Patterns of Variable Returns to Scale (VRS), this is the so-called BCC model}$$

$$\sum_{j=1}^n \lambda_j \leq 1, \text{ Patterns of Non-Increasing Returns to Scale (NIRS)}$$

$$\sum_{j=1}^n \lambda_j \geq 1, \text{ Patterns of Non-Decreasing Returns to Scale (NDRS)}$$

Not imposing any restrictions means that the envelope surface is the patterns of Constant Returns to Scale (CRS) and this becomes the CCR model.

The efficiency calculated by the CCR model is referred to as the overall efficiency. The efficiency calculated by the BCC model is referred to as the pure technical efficiency. Two efficiency values divided provide the value of scale efficiency. Pure technical efficiency specifically refers to the effectiveness of the use of the input items of each RIS in each year to determine which the situation of inputs to maximize outputs. The value of pure technical efficiency shows the efficiency of input factors. Scale efficiency shows the appropriateness of the ratio of output and input each year of each RIS. The higher value means a more suitable size and greater productivity.

Selection of Input-output Indicators

Considering the reality of China's RISs and the availability of statistics, selected three types of innovation input indicators, and three types of innovation output indicators to create a performance evaluation example aimed at the RISs of central China.

Input indicators were R & D funding, R & D personnel, and graduate students.

Output indicators were indexed papers from the Engineering Index (EI), the Science Citation Index (SCI), the Index to Scientific & Technical Proceedings (ISTP), the Chinese Social Science Citation Index (CSSCI) as well as the accepted amount of invention patent applications.

The selection of the input-output indicators has the following characteristics: (1) Indexed paper by Chinese Social Science Citation Index (CSSCI) served as an innovation output indicator. This is because a large part of R & D funding and R & D personnel are put into humanities and social science research, and CSSCI is recognized as a science indicator to measure humanities and social sciences, and (2) a graduate student served as an innovation input indicator. This is due to the graduate's more prominent role in the innovation process. The graduate students actively participated in various research activities and became an important force in scientific and technological innovation, which should not be ignored.

Correlation Analysis of Input-output Indicators

The DEA model requires the output and input indicators to meet the isotropic assumption, That is, the increase in the quantity of inputs will not reduce the number of outputs. Therefore, the selected input and output indicators must have a positive correlation. To this end, we use SPSS software to do the Pearson correlation analysis. The results are shown in Table 2. As seen in Table 2, all inputs and outputs indicators have significant positive correlations and meet the isotonic requirements. Therefore, we can use these indicators for DEA analysis.

**TABLE 2. CORRELATION ANALYSIS RESULTS
BETWEEN INPUT AND OUTPUTS**

		R&D expenditure	R&D personnel	graduate students	SCI+EI +ISTP	inventio n patent	CSSCI
R&D expenditure	<i>Pearson Correlation</i>	1	.896**	.852**	.829**	.737**	.831**
	<i>Sig. (2-tailed)</i>		.000	.000	.000	.000	.000
	<i>N</i>	24	24	24	24	24	24
R&D personnel	<i>Pearson Correlation</i>	.896**	1	.764**	.631**	.689**	.844**
	<i>Sig. (2-tailed)</i>	.000		.000	.001	.000	.000
	<i>N</i>	24	24	24	24	24	24
graduate students	<i>Pearson Correlation</i>	.852**	.764**	1	.928**	.656**	.947**
	<i>Sig. (2-tailed)</i>	.000	.000		.000	.001	.000
	<i>N</i>	24	24	24	24	24	24
SCI+EI+IS TP	<i>Pearson Correlation</i>	.829**	.631**	.928**	1	.674**	.815**
	<i>Sig. (2-tailed)</i>	.000	.001	.000		.000	.000
	<i>N</i>	24	24	24	24	24	24
invention patent	<i>Pearson Correlation</i>	.737**	.689**	.656**	.674**	1	.681**
	<i>Sig. (2-tailed)</i>	.000	.000	.001	.000		.000
	<i>N</i>	24	24	24	24	24	24
CSSCI	<i>Pearson Correlation</i>	.831**	.844**	.947**	.815**	.681**	1
	<i>Sig. (2-tailed)</i>	.000	.000	.000	.000	.000	
	<i>N</i>	24	24	24	24	24	24

** Correlation is significant at the 0.01 level (2-tailed).

Data Source of Empirical Example

In this paper, empirical data mainly comes from the following sources: the China Statistical Yearbook (accepted amount of invention patent application), the China Science and Technology Statistics Yearbook (R & D funding, R & D personnel, included papers in three systems), the Chinese Social Science Citation Index Network (indexed papers in CSSCI), statistics and analysis of China science and technology papers (included papers in three systems), and the China Education Yearbook (graduate students). In addition, we also took into account the lag

time from input to output when making relative effectiveness evaluations using the DEA method. The lag time is one year. The input indicators were selected from the years of 2002 to 2005 and output indicators were selected from the years of 2003 to 2006.

DEA Model Solution

In this study, we used EMS Version1 3.0 software and choose the input-orientated DEA model for a solution. It sequentially computes overall efficiency (EFF_{CRS}), pure technical efficiency (EFF_{VRS}), as well as the efficiency of the non-increasing returns to scale patterns (EFF_{NIRS}), then gets the scale efficiency (EFF_{SE}) using EFF_{CRS} divided by the EFF_{VRS} . Returns to scale are determined under the judgment condition put forward by Fare, et. al. (1985): When $EFF_{NIRS} \neq EFF_{VRS}$, DMU is in the stage of the incremental returns to scale (IRS); when $EFF_{NIRS} = EFF_{VRS}$, DMU is in the stage of decreasing returns to scale (DRS); and when $EFF_{CRS} = EFF_{VRS}$, DMU is in the stage of constant returns to scale (CRS). The calculation results are shown in Table 3.

Table 3 indicates that there are four, two, two and two provinces whose overall efficiency value reaches 100% in 2002, 2003, 2004, and 2005 respectively. The overall efficiency values of Henan, Hubei, and Hunan are greater than 0.9 in the continuous four years, which indicates the innovation performance of these areas is quite good and stable. The overall efficiency value of Anhui increases year by year and also maintains a good momentum of development. The overall efficiency values of Jiangxi and Shanxi are relatively poor and less than 0.9 for three years. As a whole, the mean of overall efficiency value in central China is on the decrease year by year. Therefore, relevant governments should pay more attention to the construction of RISs.

There are two main reasons for the inefficiency of DMUs: the lack of a pure technical efficiency and the lack of scale efficiency. The inefficiency of DMUs resulting from scale efficiency completely includes six provinces, including Henan (2005), Hubei (2005), Shanxi (2004), Henan (2004), Hunan (2004), and Henan (2003), which indicates these DMUs are not producing at the most efficient rate. There are eight provinces that have a lack of both pure technical efficiency and scale efficiency. They are Shanxi (2005), Jiangxi (2005), Jiangxi (2004), Shanxi (2003), Anhui (2003), Jiangxi (2003), Anhui, (2002) and Hunan (2002). Apart from production scale, these DMUs should pay attention to improving efficiency of innovation resource usage as soon as possible. There is not a DMU whose inefficiency results come from only a lack of pure technical efficiency. Additional analyses on returns to scale were made in order to find out the reason why a DMU can't exert efficiency. The results indicate Shanxi and Jiangxi exhibited increasing returns to scale in most years, but inputs of innovation resources should be increased.

Henan was in a state of constant returns to scale in 2002, and exhibited decreasing returns to scale in other years, where input of innovation resources should be decreased properly.

TABLE 3. CALCULATION RESULTS OF EFFICIENCY AND ANALYSIS SHEET OF THE RETURNS TO SCALE PROPERTIES

DMU	EFF_{CRS}	EFF_{VRS}	EFF_{SE}	Returns to scale
Shanxi(2005)	66.43%	68.83%	96.52%	IRS
Anhui(2005)	100.00%	100.00%	100.00%	CRS
Jiangxi(2005)	86.15%	88.24%	97.64%	IRS
Henan(2005)	99.74%	100.00%	99.74%	DRS
Hubei(2005)	91.72%	100.00%	91.72%	DRS
Hunan(2005)	100.00%	100.00%	100.00%	CRS
Shanxi(2004)	86.01%	100.00%	86.01%	IRS
Anhui(2004)	100.00%	100.00%	100.00%	CRS
Jiangxi(2004)	79.59%	89.28%	89.15%	IRS
Henan(2004)	99.42%	100.00%	99.42%	DRS
Hubei(2004)	100.00%	100.00%	100.00%	CRS
Hunan(2004)	98.01%	100.00%	98.01%	IRS
Shanxi(2003)	87.24%	94.50%	92.32%	IRS
Anhui(2003)	92.51%	94.93%	97.45%	DRS
Jiangxi(2003)	83.11%	95.05%	87.43%	IRS
Henan(2003)	99.79%	100.00%	99.79%	DRS
Hubei(2003)	100.00%	100.00%	100.00%	CRS
Hunan(2003)	100.00%	100.00%	100.00%	CRS
Shanxi(2002)	100.00%	100.00%	100.00%	CRS
Anhui(2002)	86.53%	89.54%	96.63%	DRS
Jiangxi(2002)	100.00%	100.00%	100.00%	CRS
Henan(2002)	100.00%	100.00%	100.00%	CRS
Hubei(2002)	100.00%	100.00%	100.00%	CRS
Hunan(2002)	98.47%	99.23%	99.24%	DRS
mean	93.95%	96.65%	97.13%	

CONCLUSION

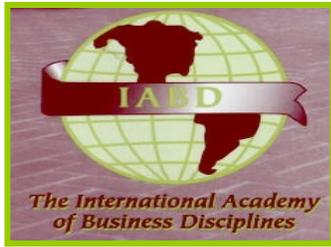
Based on RIS research and RIS construction practice, China's construction mode of a successful RIS is divided into three main types: industrial clusters, active learning and the trans-regional

innovation mode. Then the basic idea of RIS construction should consider the following: dividing the regional innovation barriers into knowledge creation barriers, knowledge acquisition (knowledge flow) barriers, enterprise innovation barriers and innovation environment barriers, and trying to put forth two new concepts to characterize the size of the barriers and their calculation methods, which are “absolute innovation barriers” and “relative innovation barriers.” Based on these, there should be research on the policy responses aimed at different innovation barriers. Finally, using the DEA method in the analysis of performance evaluation of RISs appears to provide not only utility but comparison between other research findings. Technology innovation is an important source of economic increase and is also an indispensable condition to realize leapfrogging development in the implementation of central China’s current strategy. According to the innovation performance measurement, we found that the RISs of central China have a lack of efficiency of innovation resource usage and scale efficiency, and their development is unbalanced. Looking ahead, each province of central China must face existing problems in the construction of their RISs, and firmly carry it out by focusing on the central task of efficiency to advance the realization of the significant goal of central China’s rising strategy.

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